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ROBUST OPTIMIZATION OF THE CYLINDRICITY DEVIATION FOR THE DEEP HOLE DRILLING PROCESS ON FLEXIBLE MANUFACTURING SYSTEMS

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Abstract. This article is a presentation of an application for the Robust Engineering concept [2, 3, 4, 5], applied on the manufacturing of the composite materials, on Flexible Manufacturing Systems, at high speeds and feeds. The deep hole drilling with helical drills is a difficult machining process because of the chips that must be evacuated from the machining area, but not only. This is a more complicated action if it is machined a sort of material as is Necuron. So, it must be used peck drilling. The problem that appears it the cutting parameters, that doesn't exists in the branch literature [1], explicitly.

Keywords: problem solving, coordinate measuring machine, ISO TS 16949:2002, design of experiments, ANOM

1. Introduction

The Robust Engineering approach is, in the last time taken seriously in consideration especially because of the greatest economical and technical advantages. The second reason of this reality is the fact that Taguchi's Methods were translated and putted in practice, under direct observation of Dr. Genichi Taguchi, in United States of America, and, from there, in all the other countries were English language is known [5]. Practically, the Taguchi's Methods gain a relatively big importance in the eyes of the researches from above Japan only after the invitation of Dr. Taguchi at AT&T, in USA.

The application of this method in a lot of other industrial sectors, other than electric and electronics, is not a rarity, but is a new trend. In this way, the present paper presents a series of researches developed in a plant owned by a multinational company, from the automotive industry. Applying this method, in industrial conditions, under the sign of the time and money economy, was a success. This is a consequence of the fact that, in a brief period of time, spending the smallest possible amount of time, materials, CAD / CAM resources, tools, labour, machine time, etc., there were achieved a validated optimisation.

2. Research programme presentation

2.1. The experimental approach

It's obvious the fact that the experimental research will least the principal way for obtaining reliable results regarding the studied phenomenon. It's obvious too, that the simulation techniques have their power, their importance, but, the Taguchi's Method, based on real experiments runs, fractionated as number of trial, can guide the manufacturing researches to obtain real and valuable conclusions.

The power of the Taguchi Method regarding the robust optimisation approach is the fact that this one is based on factorial fractionated arrays and on the interpretation of the experimental results by the S/N ratios [3].

The present article presents a robust optimisation of the peck drilling of deep holes, machined on a flexible manufacturing system, for a polypropylene material.

An important part of the efficientisation is assured by the fact that the critical quality characteristic was choose to be spatial deviation, that can be measured with a coordinate measuring machine. The existence of a measuring device, for a quality characteristic that can characterize the cutting process is crucial from economical point of view. In consequence, the efficientisation of the process is a higher one because the resources spent to run the trials are minimal.

2.2. The experiments

The experiments are done according with the Taguchi's algorithm, presented in an extended way on the literature [4, 5].

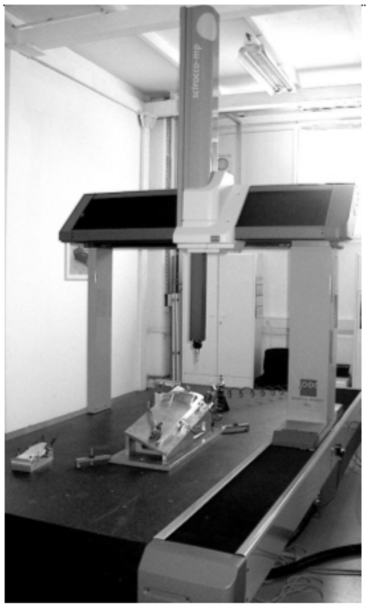

Figure 1. General view of the Coordinate Measuring Machine Brown & Sharpe Scirocco- MP, used for verification of the parts (with permission)

Figure 2. General view of the Digma GC 700 Flexible Manufacturing System (with permission)

Cylindricity deviations [μm]

Origin	1	2	3	4	5	6	7	8	9	10	Average	Std. Dev.	S/N Ratio		A	B	C
4	0,005	0,018	0,023	0,028	0,026	0,025	0,023	0,016	0,018	0,005	0,01870	0,00817	33,80523	Group 4	1	1	1
3	0,016	0,027	0,036	0,04	0,032	0,037	0,038	0,035	0,039	0,021	0,03210	0,00817	29,59723	Group 3	1	2	2
2	0,014	0,019	0,016	0,025	0,024	0,032	0,027	0,02	0,009	0,012	0,01980	0,00724	33,52187	Group 2	2	1	2
1	0,019	0,016	0,02	0,031	0,026	0,035	0,034	0,012	0,007	0,008	0,02080	0,01036	32,67663	Group 1	2	2	1

Figure 3. Experimental results obtained after running the all 4 trials of the experiment

1. Factor's average effects

A1ave=	0,02540			EA1=	0,00255
A2ave=	0,02030	Aave=	0,02285	EA2=	-0,00255
B1ave=	0,01925			EB1=	-0,00360
B2ave=	0,02645	Bave=	0,02285	EB2=	0,00360
C1ave=	0,01975			EC1=	-0,00310
C2ave=	0,02595	Cave=	0,02285	EC2=	0,00310

2. Average effects for the S/N ratios

A1ave=	31,70123			EA1=	-0,69901	% SN A1=	-2,157
A2ave=	33,09925	Aave=	32,40024	EA2=	0,69901	% SN A2=	2,157
B1ave=	33,66355			EB1=	1,26331	% SN B1=	3,899
B2ave=	31,13693	Bave=	32,40024	EB2=	-1,26331	% SN B2=	-3,899
C1ave=	33,24093			EC1=	0,84069	% SN C1=	2,595
C2ave=	31,55955	Cave=	32,40024	EC2=	-0,84069	% SN C2=	-2,595

3. Optimal factor's combination choosing

Comb	A2 B1 C1
A2	5 withdraws
B1	n=2500 rot/min
C1	vs=160 mm/min

4. Characteristic's estimations

SN es=	35,20325	(S/N ratio estimated)
cyl dev es=	0,01360	(cylindricity deviation estimated)
std dev es=	0,01081	(standard deviation estimated)

Figure 4. The results obtained computing the experimental data for cylindricity deviation optimization

In a very brief presentation, the sequences of the applied method are: choosing the levels for the experimental parameters, choose of the experimental array, running the experiment's trial, data measurements, analysis and interpretation.

The experimental array is presented in the table 1. It is an $L_4(2^3)$, that means: 4 trials, 3 experimental parameters, each one tested at 2 levels. The three experimental parameters are: the numbers of withdraws, the number of rotations per minute and the feed of the cutting tool.

The levels for the three parameters are:

- lower level for the number of withdraws: 4
- upper level for the number of withdraws: 5
- lower level for the number of rotations per minute: 2000 rot/min;
- upper level for the number of rotations per minute: 2500 rot/min;
- lower level for the feed: 120 mm/min;
- upper level for the feed: 160 mm/min.

These values are selected from the technical literature [1], in this case the cuttings tool producer. The choose of this values is for the "plastics and thermoplastics" group of materials, that include the Necuron, too. The values presented in the catalogues are generic ones, and these must be particularised for the application, and optimised, too.

Table 1. Factorial fractionated experimental array, $L_4(2^3)$ – the values of the factors levels, for the deep hole drilling

Controlled factor / Trial no.	Number of withdraws	RPN [rot / min]	Feed [mm/min]
1	4	2500	160
2	4	2000	120
3	5	2500	120
4	5	2000	160

2.3. The data analysis

Analysing data is a relatively easy to do step because of the computing systems (computers and software packages).

Practically, the Taguchi Method is based on the ANalysis Of Means (ANOM). Practically, it is compared the average effect of the measured critical quality characteristic with his average value. The same treatment is done for the S/N ratios, computed for each trial, too.

The optimal levels are the levels that help us to obtain the values bigger than the average values of the average effects (for both cases, of the critical quality characteristic and of the S/N ratio, too).

From the figure 5 can be observed the fact that all the tested parameters are approximatively the same, from the point of view of the cylindricity deviation. The parameter of biggest influence is the number of rotations per minute, which means the cutting speed. The second parameter is the cutting feed (not far as value); and the third one is the number of withdraws.

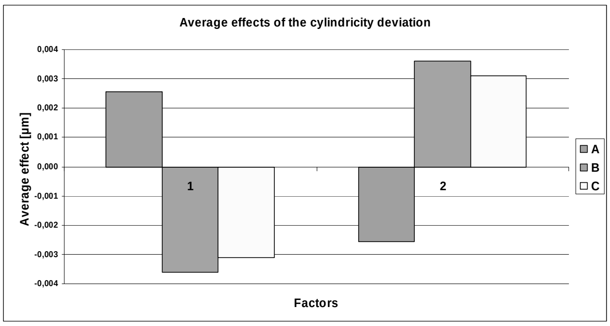

Figure 5. Graphical representation of the average effects for the cylindricity deviation

According with figure number 6, the optimal tested configuration is: A2 B1 C1. That means: 5 withdraws, 2500 rot / min and 160 mm / min. The optimised cutting parameters values put in evidence the efficiency requirement because the cutting productivity is the bigger one as much time as the feed optimal value is the bigger one, and the cutting speed is the bigger one, too. The fact that the optimal number of withdraws is 5, the bigger value influence the cutting productivity in a wrong way, but the accuracy will be the better one. Practically, because of the fact that the cutting tool failure probability is minimised, the productivity conditions are not influenced.

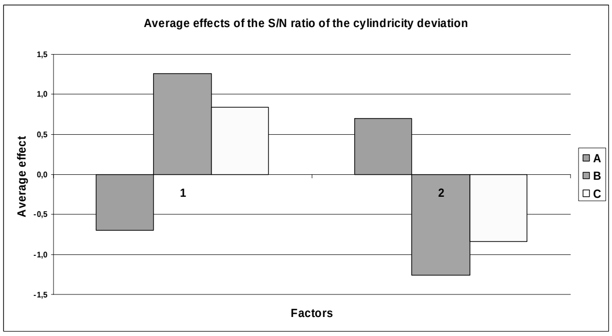

Figure 6. Graphical representation of the average effects of the S/N ratio for cylindricity deviations

3. Conclusions

According with the presented case study, the Taguchi Method can bring us to reliable results, which are useful for the manufacturing science, applied for the automotive builders sector.

The results obtained were validated during the serial production of parts, on the same technological system (machine tool – flexible manufacturing system, device, cutting tool, part material), applying the cutting parameters prescriptions according with the results of the presented researches.

The importance of that article is the fact that it presents a part of a bigger research programme, too. This research programme is aiming to "consolidate" a problem solving tool that can be implemented as easy as possible at industrial level.

This problem solving technique is based on some already known industrial management, research techniques and statistical tools. This is the fact that the proposed technique can be very easy accepted and implemented in the industrial sector.

Actually, these studies, presented in these two articles, are a part of a wider research program, experimented by the author himself in a real industrial environment. The target was to implement an original method for "problem solving".

This kind of methods is required by the ISO TS 16949 [6]:

- "The organization shall have a defined process for problem solving leading to root cause identification and elimination." (8.5.2.1. "Problem solving");

- "The organization shall define a process for continual improvement." (8.5.1.1. "Continual improvement of the organization");

- "Manufacturing process improvement shall continually focus upon control and reduction of variation in product characteristics and manufacturing process parameters." (8.5.1.2. "Manufacturing process improvement").

Those one are only 3 requirements of the technical specification ISO TS 16949 that claims the implementation of a methodology for problem solving that can be based on the Taguchi Method and on Robust Engineering principles.

In the ISO 9004:2000 [7] there it is, too, a description for a possible problem solving technique that aims not only the efficiency, but, also, the efficientisation of the entire management system or only for some parts of that one.

As a future research activity, with the present article and with his conclusions it is introduced the original idea to formulate a completed methodology for solving the problems that appear in the manufacturing processes. This methodology will be based on the Taguchi Method (but not only) and it aims to raise the efficiency of the manufacturing systems.

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